Exhibit F

Placer County Water Agency
Middle Fork American River Project
(FERC No. 2079)

DRAFT

AQ 9 - GEOMORPHOLOGY
TECHNICAL STUDY REPORT - 2008

PCWA

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TABLE OF CONTENTS

List of Tables

List of Figures

List of Maps

List of Appendices

1.0 INTRODUCTION

This report describes the geomorphology studies conducted by the Placer County Water Agency (PCWA) in accordance with the AQ 9 - Geomorphology Technical Study Plan (AQ 9 - TSP) for the Middle Fork American River Project (MFP or Project). The stakeholder-approved AQ 9 - TSP was included in Supporting Document (SD) H of the Pre-Application Document (PAD) filed with the Federal Energy Regulatory Commission (FERC or Commission) on December 13, 2007 (PCWA 2007).

Geomorphology studies, as described in the AQ 9 - TSP, were conducted for the MFP during the summer and fall of 2007 and 2008 to characterize sediment conditions in the river channels, Project reservoirs and diversions. The studies consisted of sampling potential spawning gravels and evaluating fine sediment deposition in pools along the stream reaches associated with the MFP and characterizing the size and amount of sediment capture in Project reservoirs and diversion pools. A hydrologic analysis comparing impaired and unimpaired hydrologic regimes (high flow magnitude, duration, and frequency) in bypass reaches and the peaking reach was also conducted. Lastly, studies were performed to describe the amount of large woody debris captured and PCWA maintenance practices for reservoirs and diversion pools. The following sections provide a description of the study objectives, study implementation, extent of study area, study approach, study results, and literature cited.

2.0 STUDY OBJECTIVE(S)

The study objectives of the geomorphology studies (see AQ 9 - TSP), include:

- Document sediment conditions in the bypass reaches and the peaking reach.
- Characterize sediment capture in Project reservoirs and diversion pools under existing Project operations and potential Project betterments operations at Hell Hole Reservoir.
- Develop information to assist in the identification of flow necessary to maintain geomorphic processes in the bypass reaches and the peaking reach.
- Characterize large woody debris capture in reservoirs and diversion pools and document the large woody debris management practices.

3.0 STUDY IMPLEMENTATION

Figure AQ 9-1 shows the AQ 9 - TSP objectives and the study elements and activities completed in 2005-2006, the studies completed in 2007-2008 that are documented in this report, and those studies to be completed in 2009. It also shows how information developed through the geomorphology studies will be documented and provided to the stakeholders. The following sections summarize the study elements completed; any deviations from the TSP and the rationale; outstanding study elements; and proposed modifications to the TSP.

3.1. STUDY ELEMENTS COMPLETED

Sediment Conditions in the Bypass, Peaking and Comparison Reaches

- Conduct visual V* estimates in the bypass, peaking and comparison stream reaches to characterize the amount of residual pool fine sediment.
- Collect and analyze bulk sediment samples to determine the particle size distribution (composition) and fine sediment content of potential spawning gravels within the bypass, peaking and comparison reaches.
- Plot particle size composition of spawning gravel samples as cumulative distribution curves and histograms, and determine the D_{50}, D_{16}, and D_{84}.
- Compare particle size composition and fine sediment content to standards from the scientific literature (Kondolf 1988 and 2000) and to the relevant comparison streams.

Sediment Capture in Project Reservoirs and Diversion Pools

- Summarize historic information on sediment management practices implemented at Project diversion pools, Ralston Afterbay and Middle Fork Interbay.
- Quantify and characterize sediment capture at select Project reservoirs (Hell Hole Reservoir, Ralston Afterbay, and Middle Fork Interbay) and Project diversion pools (North Fork Long Canyon Diversion Pool and South Fork Long Canyon Diversion Pool).
- Determine particle size composition of sediment captured at select Project reservoirs (Hell Hole Reservoir, Middle Fork Interbay, and Ralston Afterbay) and Project Diversion Pools (North Fork Long Canyon Diversion Pool and South Fork Long Canyon Diversion Pool).
- Initiate studies to determine sediment capture at Duncan Diversion (survey of the current diversion topography) and French Meadows Reservoir (acquisition of historical and recent topography).

Hell Hole Seasonal Storage Increase Betterment

- Estimate erosion and potential sediment loading along the shoreline of Hell Hole Reservoir associated with the Hell Hole Reservoir Seasonal Storage Increase Betterment.

Identify Flows Necessary to Maintain Geomorphic Processes in Bypass Reaches and the Peaking Reach

- Compare impaired and unimpaired hydrologic regimes (high flow magnitude, duration, and frequency) in bypass reaches and the peaking reach from existing gage records.
- Evaluate the applicability of existing USGS Regional Flood Frequency equations for application to the Middle Fork American River watershed.

Large Woody Debris Capture and Management in Reservoirs and Diversion Pools

- Characterize large wood debris (LWD) capture in Project reservoirs and diversion pools.
- Describe historical and current PCWA management practices.
- Survey and quantify LWD captured at Project reservoirs and diversion pools.
- Compare LWD amounts and function in bypass and peaking reaches above and below reservoirs and diversion pools.

3.2. Deviations from Technical Study Plan

The geomorphology studies were conducted as outlined in the AQ 9 - TSP except for the following deviations:

The AQ 9 - TSP states that V* estimates would be performed in a total of 125 pools located along the bypass, peaking, and two comparison reaches. Of the total 125 pools proposed for sampling, 17 pools were not surveyed due to either active dredge mining or to poor access conditions (see Table AQ 9-1).

3.3. Outstanding Study Elements

The following describes the outstanding study elements.

Sediment Capture in Project Reservoirs and Diversion Pools

- Quantify and characterize sediment load and particle size composition of sediment captured at French Meadows Reservoir and Duncan Creek Diversion Pool during low-pool in fall 2009. This information will be presented in the 2010 Geomorphology Study Report.

Identify Flows Necessary to Maintain Geomorphic Processes in Bypass Reaches and the Peaking Reach

- Develop a regional flood frequency curve, in consultation with Aquatic Technical Working Group (AQ TWG), to determine the magnitude and frequency of unimpaired flows for ungaged locations or locations within insufficient gaging records. Compare unimpaired peak flow derived from regional curves with impaired peak flow from gaging records
- Evaluate sediment transport conditions under different flow regimes at selected instream flow study site locations using the hydraulic models developed for the AQ 1 - Instream Flow Technical Study Plan.
- Consult with the AQ TWG to determine if additional empirical studies are necessary to characterize sediment transport under different flow regimes.
- Apply the procedures as outlined in Grant et al. (2003) for predicting the geomorphic response of study rivers and streams to Project dams.

3.4. PROPOSED MODIFICATION TO TECHNICAL STUDY PLAN

There are no proposed modifications to the AQ 9 - TSP.

4.0 EXTENT OF STUDY AREA

The study area includes the bypass reaches, the peaking reach, comparison streams, and Project reservoirs and diversion pools (see Table AQ 9-1).

5.0 STUDY APPROACH

The following describes the geomorphology study approach implemented in 2007 and 2008 which includes the methods for data collection and analysis of: (1) sediment conditions in the bypass, peaking and comparison reaches; (2) sediment capture in Project reservoirs and diversion pools; (3) Hell Hole Seasonal Storage Increase Betterment; (4) comparison of impaired and unimpaired hydrologic regimes in the bypass and peaking reaches; and (5) LWD capture and management in Project reservoirs and diversion pools.

Initial studies were performed to characterize geomorphic conditions upstream and downstream of Project dams and diversions in 2005 and 2006 (PCWA 2006 and PCWA 2007b). Phase 1 of the geomorphology studies, completed in 2005, included a review of existing information and initial field studies to characterize the geomorphic conditions. Phase 1 consisted of:

- Classification of channel geomorphology (Rosgen Level I and Montgomery-Buffington stream typing systems).
- Characterize extent and location of sediment contribution to stream channels from hillslope mass-wasting.
- Distinguish relative responsiveness of river reaches to alterations of flow and sediment regimes.
- Screening-level reconnaissance to evaluate suitability of river reaches upstream from Project facilities to serve as reference reaches.

Phase 2 of the study, completed in 2006, built upon the Phase 1 by including additional quantitative field studies. The Phase 2 studies were performed following methods provided in the 2005-2006 Existing Environment Study Plan Package which is available at the PCWA website: http://relicensing.pcwa.net/. The results of these initial studies are provided in the 2006 Physical Habitat Characterization Study Report (PCWA 2007b), which is also available on the website. The objectives for these initial studies are summarized in Figure AQ 9-1. The Phase 2 studies were performed at resource agency approved sites, and consisted of:

- Rosgen Level II stream classification.
- Rosgen Level III stream condition and channel stability characterization.

- Evaluate potential comparison streams for compatibility as reference reaches to study streams.
- Provide a geomorphic stratification of stream types for implementing focused future technical studies.

The following summarizes the study approaches implemented in 2007 and 2008, in accordance with the AQ 9 - TSP.

5.1. SEDIMENT CONDITIONS IN THE BYPASS, PEAKING AND COMPARISON REACHES

5.1.1. Residual Fine Sediment in Pools

The purpose of this study element was to characterize the amount of residual fine sediment in pools, using the V* index developed by Hilton and Lisle (1993). Excess collection of fine sediment in pools is a possible indication of insufficient magnitude or frequency of sediment transporting flows that are needed to maintain channel morphology and aquatic habitat. V* is a ratio of the volume of residual fine sediment deposited in a pool divided by the total residual pool volume. "Residual" refers to the pool dimensions at the point of zero flow.

Two different V* studies were performed: a quantitative V* assessment performed in 2006 immediately following the Ralston Ridge Fire, but prior to the runoff period; and, a visual V* estimation assessment performed in 2007. The quantitative V* analysis of fine sediment was conducted in 12 pools along the Middle Fork American and Rubicon rivers above Ralston Afterbay in the fall of 2006 (see Table AQ 9-2 and Map AQ 9-1) using the methodology developed by the United States Department of Agriculture Forest Service (USDA-FS) (Lisle and Hilton 1991, 1992 and Hilton and Lisle 1993).

The quantitative V* methodology uses multiple transects placed through individual pools to measure the depth of sediment at the bottom of the residual pool. A one-foot spacing interval for each sediment depth measurement along each transect was used for this study. The residual pool is that portion of the pool that would remain filled with water if the flow were completely stopped. The V* value calculated for each pool is an index that quantifies the proportion of the residual pool volume that is filled with fine sediment.

Following the V* quantitative analysis conducted in 2006, the AQ TWG approved the visual V* estimation approach for further characterization of the amount of residual fine sediments in pools in the AQ 9 - TSP.

In the AQ 9 - TSP, V* visual estimates were proposed at 11 sampling locations (see Table AQ 9-1) centered on the 2006 geomorphic and riparian quantitative study sites within the bypass, peaking and comparison reaches to characterize the amount of residual pool fine sediment (total of 125 sample pools). In 2007, visual V* estimates were conducted at a total of 108 pools within the bypass and peaking reaches and also at one comparison stream reach on the North Fork American River (see Table AQ 9-2 and Map AQ 9-1).

Visual V* estimates were not performed on 17 pools out of the 125 proposed samples. On the North Fork of the Middle Fork American River (comparison stream), seven pools were proposed to be sampled using the visual V* estimation technique in 2007 (see Table AQ 9-1). However, none of these seven pools were sampled because they were situated downstream from active dredge mining activities taking place during the field studies. There were an additional 10 pools in various scattered locations on other study streams that were not sampled due to inaccessible conditions. Although the V* pools used for sampling are approximately centered around the instream flow study sites, the locations of some V* pools typically extend distances of a mile or more from the instream flow sites along the stream reach. In some cases, field crews could not access these proposed sampling locations. Visual estimates for calculating fine sediment at each study pool were made by swimming the entire length of the pool with a snorkel and mask on a five to ten foot wide grid pattern, depending upon the size of the pool. The assistance of divers was not necessary. A graduated metal probe with 0.1 foot markings was used within the deeper pools to obtain sediment depths. The data collected included at least three measurements for the residual pool length, width, and depth, which was then averaged and used to estimate residual pool volume. The riffle-crest at the downstream end of the pool is the hydraulic control that defines the residual pool elevation, thus pool measurements were made according to the riffle-crest elevation. Additionally, when fine sediment was observed in a pool, the average length and width of the sediment deposits was measured.

At some locations, the fine sediment depth was determined to be only a thin coating over coarser material that could not be accurately measured with the probe, and was therefore described in the notes as "<0.1 ft" average thickness. Since a calculated volume of fine sediment was not possible with such thin layers of sediment, the results are described as "trace" amounts of fine sediment. Sediment depths equal to or exceeding 0.1 ft were used with the sediment patch length and width to calculate the volume of sediment occupying the residual pool volume.

Field sketches and photographs were also collected to document the location and amounts of fine sediment in select pools. The dominant substrate present in each pool was recorded as part of the visual observations.

5.1.2. Particle Size Composition and Fine Sediment Content in Spawning Gravels

Field Methods

Bulk sediment samples were collected from sites selected in consultation with the AQ TWG in the bypass, peaking and comparison reaches (see Table AQ 9-1) to determine the particle size distribution and fine sediment content in spawning gravels. The sampling sites selected were within or immediately adjacent to the 2006 geomorphic and riparian quantitative study sites. The bulk sediment samples provide a quantitative measure of spawning gravel particle size composition, including that portion of spawning substrates which are comprised of fine sediments.

As outlined in the AQ 9 - TSP, four bulk gravel sampling sites were selected along each of the bypass, peaking and comparison reaches, located within or immediately adjacent to the 2006 geomorphic and riparian quantitative study sites. The bulk sampling sites were selected at locations containing gravels in typical trout spawning habitat (i.e., pool tail out, pocket gravel, or riffles). Many of the proposed sampling sites were inspected in the field by the AQ TWG during spring 2007. Fifty-eight bulk samples were collected and the locations are summarized in Table AQ 9-1. The sampling sites are individually listed in Table AQ 9-3 and shown on Map AQ 9-2.

One side-by-side replicate pair of bulk samples were collected at each study site. The replicate sample provides a measure of the natural variability in particle size composition within the same gravel deposit.

The bulk sediment samples were collected using standard sedimentological practices (McNeil and Ahnell 1960) using a modified McNeil sampler (a bottomless 2 gallon bucket). Bulk samples were collected to depths approximating that of a trout egg pocket in a redd by manually pushing the sampler into the bed to a depth of at least three to five inches. Samples were collected during the low flow summer season of 2007.

The coarser sediments collected (16 mm or larger) were air dried, sieved, and weighed on site. The finer sediments were packaged in Ziploc bags, transported from the field and later air dried, sieved, and weighed. Samples were processed using a standard set of 8-inch diameter wire mesh sieves (approved by the American Society of Testing Materials), representing one-half phi interval size classes ranging from 90 to 0.062 mm.

Analytical Methods

The dry weight of each sieved size class in the bulk sample at each spawning site was recorded, and graphically plotted as a cumulative particle size distribution curve and plotted by size class frequencies (histograms). Particle size statistics that characterize the spawning gravel samples were developed from the distribution curves and histograms (discussed under results). The bulk samples within a river reach were statistically analyzed in terms of particle size composition represented by the D_{50}, D_{16}, and D_{84} size classes. To facilitate comparison of the particle size characteristics from multiple bulk samples, box and whisker plots were also prepared and grouped together to show sample results collected on the same river.

The scientific literature on spawning gravels contains much debate over the single best variable descriptor for spawning gravel quality. There is no single statistic that measures all aspects of gravel quality (Kondolf 2000). However, particle size statistics are more often used to determine the suitability of river sediments to successfully support spawning fish. Particle size is a direct indicator of: (a) the ability of the fish to move the framework gravels and construct a redd; and (b) the extent to which fine sediments may affect reproductive success.

Although there is no definitive particle size statistic universally considered optimum for trout spawning, the fisheries literature indicates that most rainbow and brown trout spawning occurs in the medium to coarse gravel size range (based on the Udden-Wentworth scale) of 8-64 mm (Kondolf and Wolman 1993; Reiser and Bjorn 1979; Grost et al. 1991). Therefore, for this study, the particle size range 8-64 mm was used to generally represent gravels that are suitable for trout spawning.

The median diameter (D_{50}) of spawning gravels from the bulk samples in this study were compared against the 8-64 mm particle size range. Gravel deposits with a D_{50} that exceed this size range were identified as being generally unsuitable for redd construction.

The D_{50} is an important statistic defining the central tendency of a particle size distribution from a bed material sample. The geometric mean, D_{84} and D_{16} of the particle size sample provide additional useful characterization of the particle size composition. The geometric mean, $dg = (D_{84}*D_{16})^{0.5}$ is another measure of central tendency, but more influenced by extremes of the gravel size distribution than the median (D_{50}). The D_{84} and D_{16} values represent one standard deviation from the median and refer to the sizes for which 84 and 16 percent of the sample is finer, respectively. These values indicate the characteristic distribution of particle sizes around the median. Together, the geometric mean, D_{50}, D_{84} and D_{16} are the useful statistical parameters for characterizing particle sizes and comparing different bulk samples.

To determine if the gravel deposit would successfully support egg incubation and fry emergence, the fine sediment content of the deposit was measured. It is widely accepted that to provide successful reproduction, gravels must be sufficiently free of interstitial fine sediment to provide adequate circulation of oxygen to the embryos, removal of metabolic waste, and permit emergence of alevin (Bjornn and Reiser 1991). Although excessive levels of fine sediment are commonly acknowledged by fisheries biologists to limit spawning success, there is no single particle size statistic that adequately relates fine sediment composition to survival (Kondolf 2000). A review of laboratory and field studies suggests that sediment finer than 1 mm can reduce gravel permeability, affecting dissolved oxygen content and removal of metabolic wastes from the redd. Sediments in the 1 to 10 mm size range are generally considered to inhibit fry emergence through interstitial gravel spaces.

Gravel within the constructed redd typically has less fine sediment than it did before redd construction (Kondolf 2000). The process of redd construction winnows fine sediments from the "potential" un-spawned gravel deposit. Kondolf (1993 and 2000) determined that the overall amount of reduction in fine sediment due to the spawning process depends on the amount of fine sediment initially present within the spawning gravel. To account for this cleaning effect, the amount of fine sediment content in the bulk samples collected from potential spawning gravels (i.e., unspawned) were adjusted using two curves (see Figures AQ 9-2 and AQ 9-3) developed by Kondolf (2000). Figure AQ 9-2 shows the percentage change in particle sizes finer than 1 mm and Figure AQ 9-3 shows the percentage change for particle sizes finer than 4 mm. The following regression equations developed from these curves were used to determine the percent of fine sediment remaining in gravels following winnowing:

- Percent of fine sediment <1 mm in winnowed gravels= 0.67 x Initial gravel percent <1 mm particle size

- Percent of fine sediment <6.4 mm in winnowed gravels= 0.58 x Initial gravel percent <6.4 mm particle size

The following criteria for spawning gravels (i.e., final sediment content of constructed redds) and high incubation success, based on Kondolf (1988, 2000), were used for this study:

- Percentage finer than 1 mm should be less than 14 percent; and
- Percentage finer than 6.4 mm should be less than 30 percent.

The fine sediment content at each potential spawning gravel site prior to spawning, and as predicted for that following spawning, are reported in this study.

5.2. Sediment Capture in Project Reservoirs and Diversion Pools

5.2.1. Estimated Sediment Loads and Particle Size Composition Captured at Project Reservoirs and Diversion Pools

The objective of this study element was to characterize sediment capture in Project reservoirs and diversion pools based on a review of existing sediment management information and data collection in the field. The characterization included quantifying the total amount of sediment captured and the distribution of particle sizes captured. Historic information on sediment management practices, including the volume and frequency of sediment removal implemented at the Project diversion pools (North and South Fork Long Canyon), Ralston Afterbay, and Middle Fork Interbay were collected from PCWA.

This report provides an analysis of sediment capture in Hell Hole Reservoir, Ralston Afterbay, Middle Fork Interbay, North Fork Long Canyon Diversion, and South Fork Long Canyon Diversion. French Meadows Reservoir and Duncan Diversion will be evaluated in 2009, with results provided in the 2010 Geomorphology Technical Study Report. The following describes the methods employed at each of the Project reservoirs and diversion pools.

Hell Hole Reservoir

<u>Estimated Sediment Loads</u>

An estimate of the volume of the deposited sediment load in Hell Hole Reservoir was determined for the exposed portion of the Hell Hole Reservoir bed. Field studies included the identification and measurement of sediment deposition areas. The field studies were conducted in October 2007 and October 2008, when the reservoir elevation was approximately 4,515 ft. The study area extended from the 4,515 ft elevation up to the reservoir inlet elevation at full pool (4,630 ft). This is a straight line distance of almost 10,000 feet, encompassing approximately the upper one-third of the reservoir. The rest of the reservoir bed was underwater at the time of the field data collection, and was therefore not surveyed and is not included in this sediment accumulation analysis.

Sediment loading was also analyzed using a second method, by comparing pre-dam elevation contours with post-dam (i.e., present-day) elevation contours. Pre-dam elevation contours were obtained from historical maps provided by PCWA. New aerial photogrammetry collected in 2007 was used to determine the post-dam elevation contour map. Changes in elevation between pre-dam and post-dam eras were used to estimate the volume of sediment captured in the reservoir. The accuracy of the pre-dam contour map was found to be limited (see discussion below), and in some areas results were found to be inconsistent with the field survey measurements. Therefore, this report relies primarily on the results obtained from the field measurements of sediment deposition rather than the pre-dam to post-dam map comparison. There are no sediment maintenance activities conducted by PCWA at Hell Hole Reservoir, so no adjustment to the estimation of the captured sediment load was necessary.

Surveys were performed initially by helicopter and by walking over the exposed portion of the reservoir bed to identify sediment depositional areas. Significant indicators of the near-original, pre-dam reservoir bed surface, such as cut tree-stumps and bedrock outcrops, were identified. The tree stumps and bedrock outcrops were important benchmarks against which the amount of sediment deposition was measured. Numerous pits were excavated with a shovel and the sediment depth measured down to the elevation of the tree stump roots; a defining layer of organic material (likely indicating the original elevation of the valley floor); or very coarse bed material. Regions of similar sediment depth were delineated in the field using a global positioning system (GPS). The regions of similar sediment depths were later defined as polygons overlying an aerial photographic base using GIS. Photographs were also taken from the helicopter and the ground to document sediment conditions.

A second, independent analysis of the sediment loads deposited was also performed using a topographic map of the pre-dam construction for Hell Hole Reservoir obtained from PCWA. The map scale is 1 in =200 ft, with 10 ft elevation contours. The survey techniques used to create the pre-dam map are unknown, and there was no statement of vertical or horizontal accuracy provided on the maps. The topographic map was geo-referenced to NAD 83 California State Plane Zone 2 coordinate system and then digitized. Recent topography of Hell Hole Reservoir was collected in fall 2007. The topographic data was collected by Air Maps USA, using aerial photogrammetric mapping techniques supported by ground control surveys. The mapping was performed only over the dry, exposed reservoir bed, which encompassed the same study area as the ground surveys described above. The rest of the reservoir bed was underwater at the time of the topographic data collection, and was therefore not surveyed or mapped, and is not included in this sediment accumulation analysis. A 2007 topographic map of the reservoir bed was created at a scale of 1 in =200 ft with 5 foot elevation contours. The vertical accuracy of the 2007 contour map is ± 2.5 ft.

GIS was used to compare the amount of elevation change between the pre- and post-dam topographic maps. In addition, six equally spaced cross-sections and a longitudinal profile that follows the centerline of the former Rubicon River was extracted from the pre- and post-dam topographic data. The cross-sections and longitudinal profile were used for comparison of bed elevation changes between the two time periods.

The accuracy of the topographic comparison between the two maps is limited by the coarser 10 ft contour spacing interval in the pre-dam topographic map. Additional sources of inaccuracy are probably associated with areas of dense vegetation indicated on the pre-dam topographic map, which likely limited survey elevation accuracy. Comparison of the pre-dam and post-dam elevation data at specific fixed reference points of elevation (benchmarks on bedrock outcrops) showed mixed results. In some cases the elevation data points matched exactly, but in other cases, the data points did not match up very well. The accuracy of the pre-dam elevation contours and therefore analytical results is probably within the range of ± 5 ft, but the accuracy is probably less in areas that had dense vegetation. Therefore, calculated elevation changes between the pre- and post-dam era that are within approximately ± 5 ft could be attributable to elevation mapping inaccuracies as much as to any real change on the ground. Considering that the ground survey measurements of sediment deposition typically were less than 4 ft, sediment accrual in most areas (see Section 6.2.1 for results), the topographic map comparison with a ±5 ft accuracy did not provide a good method for refining the ground survey measurement results. However, the comparison of pre-and post-dam topography was valid for determining if there have been substantial, larger-scale changes associated with reservoir sediment accumulation.

The extent to which sediments within the uppermost portions of Hell Hole Reservoir (accessible for visual and aerial topographic surveys) have been re-mobilized and transported further downstream outside of the study area was also considered. This could occur during periods when the reservoir was at a low-pool and high spring runoff occurs, transporting sediment further toward the dam. Under this scenario, potential sediment accumulations further downstream towards the dam would be overlooked by this current assessment. Therefore an analysis was conducted to determine how often the reservoir has been lower than the study area (i.e., below approximately 4,515 ft elevation) and when there has been inflows to the reservoir of a relatively high magnitude, sufficient to mobilize deposited sediments, particularly the coarser bed material consisting of gravel and larger size material.

Particle Size Composition

Particle sizes captured in Hell Hole Reservoir were determined by field studies, including visual observations from aerial and ground surveys and by quantitative sampling of reservoir bed particle sizes. The volume of sand, gravel, and cobble captured in the reservoir since construction was completed in 1966 was calculated. Fieldwork was conducted in fall 2007 (pebble counts, bulk sampling, and soil pits) to identify surface and subsurface particle sizes over the exposed reservoir bed during low water surface elevation. The pebble counts were performed using standard methods (Harrelson et al. 1994).

Bulk samples were primarily collected where there was some evidence of sediment deposition, such as in the vicinity of the overbank regions adjacent to the former stream channel, and near where tributary channels enter the reservoir. The sediment texture in these regions was often heterogeneous and included size fractions coarser than sand. Bulk samples were collected to a depth of approximately 1.5 ft using a shovel. The bulk sample material was collected and sieved in a laboratory using standard ASTM screens at one-half phi intervals down to the lower end of the sand sized fraction, and then each sieved portion was weighed. Silt and clay sized sediment were combined together and characterized as "fines." Both the pebble counts and bulk sample data were plotted as frequency histograms and cumulative particle size distribution curves.

Soil pits were dug at various locations and photographed to assist with a visual determination of the types of particle sizes present. Soil pits were concentrated in areas where the particle size gradation was overwhelmingly sand size material. The soil pits were dug with a shovel to a depth of approximately 1.5 ft. A sand card was used as a reference to characterize the texture of the sand. All of the soil pit material was categorized according to the proportional amount of sand, and any coarser gravel, or cobble material that may have been present.

The particle size analysis was organized into six categories as follows:

- Sand (i.e., "fines") is material finer than 2 mm, and for purposes of this analysis included material that may be of silt or clay size;
- Fine Gravel ranges from 2 mm to 8 mm;
- Medium Gravel ranges from 8 mm to 45 mm;
- Coarse Gravel ranges from 45 mm to 64 mm;
- Cobble ranges from 64 mm to 256 mm; and
- Boulder/bedrock is greater than 256 mm.

The locations of the pebble counts, bulk samples, and soil pits were recorded with a GPS. Additionally, the reservoir bed was delineated with the GPS into a series of polygons that define relatively homogeneous regions of representative particle sizes. Bedrock material exposed within the full-pool reservoir footprint was determined both in the field and using aerial photography.

and diversions. Woody material smaller than these dimensions may consist of leaves, twigs, and branches, but is not considered LWD.

The number of LWD that fit the defined criteria was tallied on the small and medium diversions. This was done by walking and/or driving along North Fork Long Canyon Diversion, South Fork Long Canyon Diversion, Duncan Diversion, Middle Fork Interbay and Ralston Afterbay. On the larger Project reservoirs LWD was counted by walking, driving, or boating around the reservoirs. Photographic documentation of the LWD present was also collected.

Large woody debris in the bypass and peaking reaches above and below reservoirs and diversion pools was collected, except for above Hell Hole Reservoir, as part of the 2006 Physical Habitat Characterization Study (PCWA 2007b). This information was used to help characterize the fate of LWD transport into Project reservoirs and diversion pools.

6.0 STUDY RESULTS

6.1. SEDIMENT CONDITIONS IN THE BYPASS, PEAKING AND COMPARISON REACHES

6.1.1. Key Findings

- The V* values at all sampling sites in study stream reaches were less than 0.1.
- All study streams contained suitably-sized spawning material for trout, based on the gravel size criteria used in this report (8-64 mm).
- The fine sediment content within the bulk spawning gravel samples was within the established criteria to support high trout reproductive success.

6.1.2. Results

Fine Sediment in Pools

The results of the quantitative V* measurements conducted in 2006 are provided in Table AQ 9-2 (previously presented in the 2006 Physical Habitat Characterization Study Report PCWA 2007b). The results of the visual V* measurements conducted in 2007 are also provided in Table AQ 9-2. The table summarizes the residual pool measurements, the average volume of fine sediment stored within the pool, and the calculated V* index. Map AQ 9-1 depicts the locations where the pools were sampled.

The V* values at all sampling sites in study stream reaches were less than 0.1, indicating very little fine sediment storage. V* values less than 0.10 are considered to be indicative of a relatively low proportion of fine sediment storage in pools, and indicates that there is adequate flow to maintain pool volume and transport fine sediments on a regular basis. Pools with V* values ≤0.10 can be characteristically described as having fine bed material confined to small and discontinuous deposits in eddies or in slack water areas (Lisle and Hilton 1999).

Based on visual observations of the pool substrate indicate that the majority of the pools contained bedrock or boulders. Cobble and/or coarse gravels were also noted within each of the pools surveyed. In most cases, the fine sediment was a thin coating (less than 0.1 ft thick) located within the interstitial spaces of the coarse bed material. At the few pool locations where thicker fine sediment deposits were present, the deposits were located primarily along the margins of the residual pool in slack water areas, or in the velocity shadow of larger boulders.

Duncan Creek

V* was determined for 10 pools at the instream flow study site D8.3 (see Table AQ 9-2). For all pools, the average thickness of the fines present ranged from trace amounts (<0.1 ft) to 0.2 ft thick. Visual V* estimates were all below the 0.1 threshold for very low fine sediment storage, with some pools having no sediment present.

Middle Fork American River

V* was quantitatively measured along the Middle Fork American River in 2006 along two reaches (French Meadows Reservoir to Middle Fork Interbay and Middle Fork Interbay to Ralston Afterbay), and visually estimated in 2007 along three reaches (French Meadows Reservoir to Middle Fork Interbay, Middle Fork Interbay to Ralston Afterbay, and below Ralston Afterbay). Two pools from French Meadows Reservoir to Middle Fork Interbay and six pools from Middle Fork Interbay to Ralston Afterbay were quantitatively measured in 2006 with a weighted V* of 0.03 for both reaches. In 2007, a total of 26 pools were visually estimated along the three reaches. The study results along all of reaches on the Middle Fork American River in both 2006 and 2007 revealed a V* well below 0.1 (see Table AQ 9-2). Visual V* estimates for each pool along the entire Middle Fork American River (bypass and peaking reaches) ranged from 0.07 to <0.01, with most below 0.03.

Rubicon River

V* was both quantitatively measured along the Rubicon River in 2006 and visually estimated in 2007 along two reaches (Hell Hole Reservoir to confluence with South Fork Rubicon River and the confluence with South Fork Rubicon River to Ralston Afterbay). One pool was quantitatively measured in 2006, just upstream of Ralston Afterbay. A total of 26 pools were visually estimated for V* in 2007, nine pools from Hell Hole Reservoir to confluence with South Fork Rubicon River and 17 pools from confluence with South Fork Rubicon River to Ralston Afterbay.

The results of the V* study in 2006 and 2007, showed that all pools were below 0.1 for fine sediment (see Table AQ 9-2). The weighted visual V* conducted in 2007 was 0.005 from Hell Hole Reservoir to the confluence with South Fork Rubicon River and 0.017 from the confluence with the South Fork Rubicon River to Ralston Afterbay.

Long Canyon Creek

Fine sediment was visually assessed at 10 pools along each of the North Fork Long Canyon Creek and South Fork Long Canyon Creek study reaches, and nine pools were assessed along Long Canyon Creek (see Table AQ 9-2). Weighted visual V* estimates along North Fork Long Canyon Creek, South Fork Long Canyon Creek, and Long Canyon Creek were 0.004, 0.002, and 0.00 (no sediment present), respectively. All of which is well below the 0.1 threshold for fine sediment storage in pools. Pools along the mainstem of Long Canyon Creek contained the least amount of fine sediment with seven of the nine pools surveyed containing no fine sediment.

Comparison Streams

Two sites were sampled in river reaches not associated with the MFP. These river reaches are located in the North Fork American River and the Middle Fork American River watersheds and were sampled to compare with data collected on the bypass and peaking reaches. Specifically, the North Fork of the Middle Fork American River (NFMF2.3) was used for data comparison with the Middle Fork American River above Ralston Afterbay (MF26.2) and Middle Fork American River above Middle Fork Interbay (MF36.2). The North Fork American River below Ponderosa Bridge (NF31.3) was used for data comparison with the peaking reach along the lower Middle Fork American River downstream of Ralston Afterbay (MF4.8 and MF14.1).

North Fork of the Middle Fork American River

Fine sediment was quantitatively measured in 2006 for three pools at NFMF2.3. V* values were all below 0.1, ranging between 0.03 and 0.07, with a reach average of 0.05 (see Table AQ 9-2).

Findings from the 2006 and 2007 studies from the comparable Middle Fork American River study stream reaches had similarly low V* values to the North Fork of the Middle Fork American River. The 2006 and 2007 Middle Fork American River V* values ranged from 0.000 to 0.07 (see Table AQ 9-2).

North Fork American River

Visual V* estimates were conducted on the North Fork American River in 2007 at five pools (NF31.3). Fine sediment in the pools ranged from 0.00 (no fine sediment) to 0.02, with a reach average of 0.01 (see Table AQ 9-2).

The North Fork American River is a comparison stream to the peaking reach of the Middle Fork American River below Ralston. The V* results between the two rivers are similar, with the pools in the peaking reach ranging from 0.0003 to 0.07, and a reach average of 0.002.

Particle Size Composition and Fine Sediment Content of Spawning Gravels

The statistical results from the analyses of bulk sediment samples are presented in Table AQ 9-3. Histogram and cumulative particle size distribution curves from each bulk sample are available in Appendix A. For a comparison of all samples collected from a given river, Appendix B contains box and whisker plots of the bulk gravel particle size statistics. The amount of fine sediment within the potential spawning gravel sample is shown in Table AQ 9-4.

The D_{50} of the bulk samples at all the sampling locations were within the range of suitably sized spawning material, 8-64 mm used by trout (see Appendix A, Appendix B, and Table AQ 9-3).

Results indicated that the fine sediment content for all of the gravel samples were within the established criteria to support high reproductive success. The fine sediment levels associated with 18 of the total 58 unspawned bulk samples on study streams exceeded the criteria of less than 30 percent fines at the 6.4 mm size threshold. However, accounting for the process of winnowing of fine sediments during spawning, all of the gravel samples were well within the criteria for fine sediment content at the 6.4 mm size threshold. Two of the eight unspawned bulk samples on comparison streams (both on the North Fork American River), also exceeded the fine sediment criteria at the 6.4 mm size threshold, but accounting for the spawning process, both of these samples were also within the criteria.

One (MF4.13) of the 58 unspawned bulk samples slightly exceeded the criteria of less than 14 percent fines at the 1 mm size threshold on the study streams. Accounting for the process of winnowing of fine sediments during the spawning process, this gravel sample was within the criteria for fine sediment content at the 1 mm size threshold. One of the eight unspawned bulk samples on comparison streams (North Fork American River), also exceeded the fine sediment criteria at the 1 mm size threshold; but, when accounting for the spawning process, this sample was within the limits established for this report.

<u>Duncan Creek</u>

Four bulk samples were taken from the instream flow study site on Duncan Creek (D6.3). The samples were collected in either pool tail outs or in step-pool sections where gravels had deposited in pockets in the velocity-shadow created by large boulders. The D_{50} ranged from 11.6 to 22.3 mm, and the geometric mean ranged from 11.6 to 17.6 mm (see Appendix A, Appendix B, and Table AQ 9-3). All of the samples were within the range of suitable spawning gravel sizes. The replicate samples, SG3 and SG4 (side-by-side sample) had very similar particle sizes (see Table AQ 9-3). The geometric means of the samples at both sites were similar (SG3=16.2 mm and SG4=17.6 mm).

The percentage of fines smaller than 1 mm in all samples was quite low (less than 1 percent), well under the 14 percent threshold, even before accounting for cleansing effect by fish spawning (see Table AQ 9-4). Fines less than 6.4 mm ranged between 10 and 22 percent in the un-spawned bulk sample, all less than the 30 percent threshold for fine sediment.

Middle Fork American River

Four or five bulk samples were taken at each instream flow study sites (5 sites, total of 21 samples) on the Middle Fork American River. Three sites were located along the Middle Fork American River bypass reach: Middle Fork American River below French Meadows Reservoir (MF44.7), Middle Fork American River above Middle Fork Interbay (MF36.2), and Middle Fork American River above Ralston Afterbay (MF26.2). Two sites were located in the peaking reach: Middle Fork American River at the Otter Creek confluence (MF14.0) and Middle Fork American River near Buckeye Bar (MF4.8). The results of the bulk particle size sampling along the Middle Fork American River are described separately for each instream flow study site.

MF44.7

Four bulk samples were taken along the margins of step pools or in pool tail outs. The D_{50} ranged from 10.0 to 15.2 mm, and the geometric mean ranged from 7.4 to 9.7 mm (see Appendix A, Appendix B, and Table AQ 9-3). All of the samples were within the range of suitable spawning gravel sizes for the size of fish present. The replicate samples (SG2 and SG3) had nearly identical geometric means (SG2=9.6 mm and SG3=9.7 mm) (see Table AQ 9-3).

The percentage of fines smaller than 1 mm in all samples was less than the 14 percent threshold, ranging from 7.5 percent up to 10.6 percent (see Table AQ 9-4). Fines less than 6.4 mm slightly exceeded the 30 percent threshold at three of the four sampling sites. However, after accounting for the effects of winnowing fine sediment due to spawning, the fine sediment content for fines less than 6.4 mm would be reduced to 18 to 22 percent of the sample, within the limits established for this report.

MF36.2

Five bulk particle size samples were taken along a run where a velocity-shadow was created by large boulders or along the margins or pool tail outs. The D_{50} ranged from 7.9 to 36.8 mm, and the geometric mean ranged from 7.5 to 15.2 mm (see Appendix A, Appendix B, and Table AQ 9-3). The replicate samples (SG1 and SG2) had similar geometric means (SG 1=9.0 mm and SG2=8.4 mm) (see Table AQ 9-3).

The percentage of fines smaller than 1 mm in all samples was less than the 14 percent threshold, ranging from 1.1 percent up to 2.5 percent (see Table AQ 9-4). Fines less than 6.4 mm were 19 and 26 percent for SG4 and SG5, respectively, before accounting for the effects of cleansing by spawning activity. SG1 and SG2 slightly exceeded the 30 percent threshold with 31 and 36 percent fines, respectively. However, accounting for the winnowing of fines during redd construction, the percent fines less than 6.4 mm would be reduced to 18 and 22 percent for SG1 and SG2, respectively.

between 1.1 and 3.0 percent of the total sample at each sampling location (see Table AQ 9-4). Fines less than 6.4 mm ranged between 16 and 25 percent, all less than the 30 percent threshold for fine sediment. As a comparison to MF26.2 and MF36.2, fines less than 1 mm were similar between the Middle Fork American River bypass reaches and the North Fork of the Middle Fork American River. The percent of fines less than 6.4 mm from the North Fork of the Middle Fork American River bulk samples were less, with a maximum of 25 percent (SG2) compared to 37 percent at MF26.2 (SG3 and SG4), although all samples from the bypass reach were within the limits established in this report for post-spawning fine sediment composition.

North Fork American River

Four bulk samples were taken along the North Fork American River in either pool tail outs or along low gradient riffles. The D_{50} ranged from 11.3 to 41.7 mm, and the geometric mean ranged from 7.8 to 25.5 mm (see Table AQ 9-3). The bulk samples from the peaking reach and the North Fork American River were similar.

The percentage of fines smaller than 1 mm in all samples ranged between 3.1 and 14.1 percent of the un-spawned gravel material (see Table AQ 9-4). Sample SG3 just exceeded the threshold of 14 percent (14.1 percent), but accounting for winnowing of fines during redd construction, the spawned material would have a 9.4 percent fine sediment content, well within the threshold. Fines less than 6.4 mm ranged between 17 and 33 percent. Two of the four samples were below the threshold, but samples SG2 and SG3 were comprised of 32 and 33 percent fine sediment content, respectively, both slightly exceeding the threshold. This is similar to the data collected along the instream flow study reaches at MF4.8 and MF14.1, both of which had two samples exceeding the threshold at the 6.4 mm. For samples SG2 and SG3, the additional cleaning during spawning would reduce the sediment content for fines less than 6.4 mm to 19 percent, which is within the limits established for this report.

6.2. Sediment Capture in Project Reservoirs and Diversion Pools

6.2.1. Key Findings

Hell Hole Reservoir

- Approximately 443,500 cubic yards of sediment has accumulated in Hell Hole Reservoir since Project operations began (1966-2006). This sediment accumulation rate is consistent with California watersheds that yield low sediment loads.
- The vast majority of the coarser bedload material (gravels and larger) captured in Hell Hole Reservoir has deposited within the sediment accumulation study area. There is likely a smaller proportion of sediment deposition, mostly sands, downstream from the study area that is not accounted for in this analysis.
- Sand-sized particles comprised the majority of the total sediment accumulation (72 percent). Gravels of medium and coarse size ranges (8-64 mm) together

comprised approximately 12 percent (52,000 cubic yards) of the total volume of sediment accumulation. Average annual gravel load captured in Hell Hole Reservoir was approximately 1,250 cubic yards/yr. The remaining sediments captured include 6 percent fine gravels (2-8 mm), 3 percent cobble (64-256 mm), and 6 percent boulder (>256mm).

North and South Fork Long Canyon Creek Diversions

- Cumulatively, PCWA has removed small amounts (3,370 cubic yards) of sediment from the North Fork Long Canyon Diversion over an 11-year period from 1996-2006. Of the 3,370 cubic yards removed, most of the sediment (60 percent) was sand (<2 mm). Approximately 20 percent of the total volume, or 675 cubic yards, was medium (8-45 mm) and coarse gravel (45-64 mm) sizes.
- Cumulatively, PCWA has removed small amounts (5,350 cubic yards) of sediment from South Fork Long Canyon Diversion over the 11-year period from 1996-2006. Of the 5,350 cubic yards removed, approximately 62 percent of the total volume or 3,300 cubic yards was medium gravel (8-32 mm) and coarse gravel (45-64 mm) that are typical of sizes used for trout spawning.
- Both diversions have low trap efficiencies, so that most of the suspended sediment load (predominantly sand) is transported over the dam during high flow events. Bedload sediments (coarse sand, gravel, and cobble) also pass over the diversion dams whenever the diversion pools become nearly filled with sediment or during very large storm events that can entrain material from the diversion pool. Sediment removal for maintenance purposes only extracts the portion of the sediment load from the upstream watershed that is deposited in the diversion.

Ralston Afterbay

- The total sediment load contribution to Ralston Afterbay between 1966-2006 was approximately 2,013,000 cubic yards, which represents an average annual sediment load of 50,325 cubic yards/yr.
- Approximately 25 percent of the sediment deposited in Ralston Afterbay, about 503,000 cubic yards, was in the medium (8-45 mm) and coarse (45-64 mm) gravel size ranges. On an annual average basis, this represents about 12,575 cubic yards/yr of gravel deposition in the reservoir. These estimates probably over-estimate the actual rate of gravel entrapment because part of the 2,013,000 cubic yards of sediment load that has been deposited very close to Ralston Afterbay Dam, although unanalyzed, is likely to consist of fine sediment with little or no gravels.
- PCWA has initiated a pilot sediment management project at Ralston Afterbay to create sediment storage capacity in the reservoir to help maintain operational flexibility and to restore some of the coarse sediment recruitment to the channel downstream from the reservoir. As part of this sediment management program, PCWA placed about 48,000 cubic yards of sediment (mixed sands, gravels, and

larger) on Indian Bar immediately downstream of the dam in 2002. This effectively "recycled" a portion of the 503,000 cubic yards of gravel size material previously trapped in the reservoir, making it available for recruitment to the downstream reach to enhance habitat for trout and benthic invertebrates.

Middle Fork Interbay

- Sediment capture in Middle Fork Interbay, since the beginning of Project operations, was approximately 144,000 cubic yards based on maintenance records. This represents an average annual sediment load of 3,600 cubic yards/yr delivered to Middle Fork Interbay over the 40-year period from 1966-2006.
- The total entrapment of medium (8-45 mm) and coarse (45-64 mm) sized gravel over the 40-year period of record was approximately 36,000 cubic yards, or 900 cubic yards/yr on an annual average basis.

6.2.2. Results

Hell Hole Reservoir

Estimated Sediment Loads

Map AQ 9-3 is an aerial photograph of Hell Hole Reservoir depicting the study area that was analyzed for this report. There were large portions of the reservoir over which there has been relatively little sediment deposition. Two primary indicators of near original, pre-dam bed elevations include exposed bedrock outcrops and old cut tree stumps. Map AQ 9-4 shows a close-up of the study area with large sections of the reservoir bed having visible cut tree-stumps and bedrock exposures inside the footprint of the reservoir at full pool (elevation 4,630 ft). Tree stumps were very numerous in many locations (on the order of several thousand). Only a few representative areas with denser clusters of tree stumps could be feasibly recorded with GPS data points, as depicted on Map AQ 9-4. Appendix C provides a set of photographs taken from the helicopter and ground surveys of areas with old cut tree stumps and bedrock exposures (see Appendix C, Figures C-1, C-2, C-3, and C-4). Most of the old cut tree stumps were located along the south side of the Rubicon River channel, although there were also some stumps on the north side, (see Appendix C), mostly situated closer to the banks of the river.

Map AQ 9-5 shows the measured depths of sediment accrual over the Hell Hole Reservoir study area. Although tree stumps indicate areas where the reservoir bed elevation has not changed substantially, sediment accumulation around the stumps was typically sandy material, measured to be from 0.25 ft to 1.5 ft depth. However, in a few locales tree stumps were almost completely or entirely buried. At these locations (see Map AQ 9-4), sediment accumulation was measured at depths greater than 1.5 ft up to about 4 ft depth. There were no ground indications of sediment depths accruing to greater than 4 ft anywhere in the reservoir.

Exposed bedrock areas are the original bed elevation and therefore represent areas with 0.0 ft of sediment accrual. Bedrock exposures were found on both the north and south side of the Rubicon River channel, along the entire 10,000 ft length of the visible reservoir bed. Around the perimeter of the reservoir near the full-pool elevation, the valley walls are typically steep, and are either composed entirely of bedrock, or bedrock mixed with boulders and large cobble, but there is virtually no sediment deposition in these areas (see Maps AQ 9-4 and AQ 9-5).

Areas of the reservoir where relatively greater amounts of sediment deposition (>1.5 ft), predominantly sands (but also gravels mixed with sand) were present on the north side of the reservoir in the lower half of the study area. This area is close to several small tributaries that enter the reservoir, including Grayhorse Creek (see Map AQ 9-5). It appears that Grayhorse Creek and smaller (unnamed) tributaries are delivering sediments that include sand, gravel, and cobble size material to the reservoir (see Appendix C, Figure C-6, and Figure C-7). Importantly, this is a much wider section of the reservoir study area (approximately 950 ft width) than the upper half of the study area (approximately 350 ft width), so there is a larger area over which high flows can spread out as they overbank the low-flow channel of the Rubicon River during backwater conditions, providing greater opportunities for sediment deposition.

A geographic information system (GIS) was used to calculate the volume of sediment accrual. The surface area of each of the polygons defining the amount of sediment deposition was multiplied by their respective measured depths of sediment (see Map AQ 9-5), resulting in a total volume of sediment accrual for the reservoir. The total amount of sediment deposition calculated from the field measurements was approximately 443,500 cubic yards. Since the reservoir has been collecting sediments for 41 years (Hell Hole Dam became operational in 1966), this would be an average annual sediment accumulation rate of approximately 10,800 cubic yards per year. It should be recognized that the annual sediment accrual rates calculated here are simply a mathematical accounting of sediment loading on an annualized basis for the entire 41 year period of record. In reality, sediment loads do not move as an average annual amount. Rather, sediment transport occurs episodically, with much greater amounts of sediment moved in years with very high flows, and much smaller amounts moved during years with only low flow events.

The sediment load contribution to Hell Hole Reservoir calculated in this analysis is therefore very close to that for low-yielding watersheds in California. The average annual sediment load contribution to California streams that are considered to carry a low sediment load is approximately 80 tons/sq mi/yr (Leopold 1994). The drainage area to Hell Hole Reservoir is 114 sq mi. Based on an annual average sediment load of 10,800 cubic yards/yr, the contribution per square mile from the watershed upstream of Hell Hole Reservoir is 95 cubic yards/sq mi/yr which is approximately 107 tons/sq mi/yr.

Particle Size Composition

A total of 12 bulk samples and eight pebble counts were collected to quantitatively analyze particle size composition over relatively homogeneous regions of the reservoir.

Map AQ 9-6 shows the locations of the particle size sampling. The Hell Hole Reservoir bulk sample and pebble count cumulative particle size distribution curves and histograms are provided in Appendix D. Additionally, thirty-three soil pits were dug and visually inspected to qualitatively identify the predominant particle sizes present (see Map AQ 9-6). Particle size distribution curves were not created for soil pit samples because they were located in areas containing nearly 100 percent sand. Photographs of a typical soil pit are provided in Appendix C, Figures C-8, and C-9. In addition, visual observations of the percent contribution of different size material (i.e., sand, gravel, cobble, and boulder/bedrock) were also recorded for each sediment region delineated.

The bulk samples, pebble counts, soil pit data, and field observations were collectively used to determine the particle size composition over the GPS delineated polygons in the reservoir. Map AQ 9-7 shows the reservoir particle size composition data delineated into 25 polygons distributed over the reservoir footprint. The proportion of sand, fine gravel, medium gravel, coarse gravel, cobble, and boulder/bedrock present in each of the defined polygon regions of the reservoir (see Map AQ 9-7) are listed in Table AQ 9-5. Sixteen of the 25 defined regions of the reservoir were predominantly sand, including the largest areas of the reservoir. Medium and coarse size gravels used by spawning trout represented more than 5 percent of the particle size composition of sediments in 15 of the 25 regions. Most of the portion of the reservoir along the alignment of the Rubicon River channel itself contained higher proportions of the gravel material, as well as overbank regions near the low-flow channel.

Overall, the particle size composition of the reservoir was predominantly sand, with regions of sand mixed with gravels, and with large interspersed areas of bedrock. There were smaller areas of cobble and cobble mixed with gravels and boulders situated on the former banks of the Rubicon River. These former river banks are close to the pre-dam elevation based on the presence of old cut tree stumps with root exposure (see Appendix C, Figure C-4).

Integrated Analysis of Reservoir Sediment Deposition and Particle Sizes

Sediment loading to Hell Hole Reservoir was independently calculated comparing the pre- and post-dam topographic mapping. A longitudinal profile of pre- and post-dam topography following the thalweg of the Rubicon River was graphically plotted in Figure AQ 9-4. The locations of the seven cross-sections are shown in Map AQ 9-8 and the cross-section plots are provided in Appendix E. Overall, the river channel elevation has not substantially changed, and retained the same breaks in gradient in the post-dam topography as in the pre-dam topography. Throughout most of the length of the channel longitudinal profile, the pre-dam elevation plots were slightly higher than the post-dam elevation, an indication that there has possibly been some incision (i.e., lowering) of the river bed channel. From station 1,250 (approximately elevation 4,610 ft) to station 10,000 (approximately elevation 4,515 ft), the elevation of the river bed was within 5 ft of the pre-dam elevation, which is within the range of error associated with this part of the analysis. As such, it cannot be definitively concluded that any aggradation or incision has occurred along the thalweg of the channel. Ground survey measurements where bars of gravel and sand were observed along the low-flow channel indicated at least some small areas of aggradation along the former river bed. However, if there had been a substantial amount of sediment aggradation associated with the post-dam survey, the longitudinal profile would have shown a pronounced flattening of the gradient, and the post-dam elevations would have been higher than the pre-dam elevations. There are apparently some inaccuracies associated with the mapping of the pre-dam elevations in the upstream-most section of the channel and reservoir (station 0 to 1,250), which showed a more pronounced down-cutting of the channel (see Figure AQ 9-4). Field surveys indicated that sediment accumulation has occurred in this part of the reservoir (near confluence of Five Lakes Creek and Rubicon River).

GIS was also used to calculate the volume of sediment accrual comparing the pre- and post dam topography. When all of the aggradational areas of the reservoir were summed together, the total increase in sediment volume is 272,000 cubic yards. Assuming a ±5 ft error range associated with the amount of elevation change in the reservoir, sediment loading could be as high as 1,171,500 cubic yards, or as low as 32,700 cubic yards. These estimates are within the range of the 443,500 cubic yards of sediment loading calculated based on the field measurement method, as discussed above.

GIS was used to calculate the volume of sand, gravel, cobble, and boulder size material that has deposited in the reservoir. This was accomplished by integrating the data for sediment accrual determined from field measurements (see Map AQ 9-5) with the particle size gradation data (see Table AQ 9-5 and Map AQ 9-6). Results are provided in Table AQ 9-6 which shows the deposited volume of sediment in each of the particle size classes for each region of the reservoir. The volume of newly deposited sediment since the beginning of Project operations corresponds to a numbered region on Map AQ 9-7. Sand comprised the greatest proportion of aggraded sediments, approximately 72 percent (321,650 cubic yards), with the remaining particle size categories (fine gravel, medium gravel, coarse gravel, cobble, and boulders) ranging from 3 percent up to 9 percent of the total volume. The volume of combined medium (8-45 mm) and coarse (45-64 mm) size gravels (typically used for spawning) comprised 12 percent of the total volume of aggraded sediments, approximately 52,000 cubic yards since Project inception. This is equivalent to an average annual medium and coarse gravel load contribution of approximately 1,250 cubic yards/yr.

GIS was also used to apportion the total sediment load based on the comparison of the pre- and post-dam topographic mapping into deposited volumes of sand, gravel, cobble, and boulders. The same particle size data provided in Table AQ 9-5 and Map AQ 9-7 was used for this assessment, but the volume of sediment accumulation was determined by differential comparison of the pre- and post-dam topographic maps using GIS. Based on the pre- and post-dam comparison approach, the relative proportions of deposited sediments were sand (66 percent), fine gravel (6 percent), medium gravel (7 percent), coarse gravel (10 percent), cobble (4 percent), and boulders (6 percent). This is very similar to the results using the field measured data of sediment accumulation. The total amount of medium and coarse gravel deposition is approximately 49,000 cubic yards, which is very close to the 52,000 cubic yards calculated from the field measurements.

While only the upper one-third of Hell Hole Reservoir was analyzed for sediment accumulation, the vast majority of water and sediment recruited from the watershed comes into this region of the reservoir. The Rubicon River (a 4th order stream), Five Lakes Creek (a 3rd order stream), and Grayhorse Creek (a 2nd order stream) all enter within the study area of the reservoir. A couple of other un-named first order channels also enter within this part of the reservoir. There are six additional drainages that enter Hell Hole Reservoir downstream of the study section, but all are small, first order streams (only Cottonwood Creek is named). Therefore the majority of the sediment recruitment into the reservoir is accounted for in this analysis.

In order to characterize the extent to which this analysis accounts for most of the sediment that is likely to have been recruited and deposited in Hell Hole Reservoir, an additional evaluation was performed. This evaluation determined how frequently the reservoir has been at a lower elevation than for this current analysis (i.e., below elevation 4,515 ft), and when there have been simultaneous high magnitude inflows to the reservoir that could mobilize previously deposited sediments, transporting them downstream of the study area.

Figure AQ 9-5 plots reservoir water surface elevation against inflow magnitude for a 29-year period of record from October 1, 1974 to September 30, 2003. Average daily inflow and water surface elevation data were concurrently available for 1975 to 2003. The horizontal line plotted on Figure AQ 9-5 is the downstream elevation 4,515 ft, for the exposed, dry reservoir bed area analyzed in this study. The red arrows on the chart show the dates when inflow was greater than 2,000 cfs and water surface elevation was less than 4,515 ft. Two thousand cfs was used as a benchmark for sediment transport because it was a commonly occurring annual high flow into the reservoir. There was a total of 128 days when discharge was greater than 2,000 cfs over the period of record, and of those 128 days, only 6 days when the reservoir water surface elevation was simultaneously lower than 4,515 ft. The rest of the time (122 days) inflows exceeding 2,000 cfs occurred when the reservoir was at a higher elevation; therefore, backwater would have occurred above the 4,515 ft elevation and sediments would have been deposited within the study area analyzed for this report. As a note, the four greatest inflows of record occurred when the water surface elevation was higher than that analyzed in this report, when the Rubicon River would have been carrying the most sediment into the reservoir backwater area. The data indicate the vast majority of bedload deposition is occurring within the dry, visible portion of the reservoir analyzed for the current study (above elevation 4,515 ft).

North Fork Long Canyon Creek Diversion

Estimated Sediment Loads

The North Fork Long Canyon Diversion Dam is a 10 foot-high, 120 foot-long concrete gravity structure with a small diversion pool of less than one ac-ft of storage (PCWA consisting of six or more pieces was also observed within the first mile upstream. Within one mile downstream of the diversion, 22 pieces of wood longer than 15 feet were observed in 2006, some of which comprised a log jam (PCWA 2007b).

North Fork Long Canyon Creek Diversion and Dam

Three pieces of LWD were observed along the high water mark where the channel flows into the reservoir. The orientation of the wood appeared to indicate that they have fallen in place, rather than recruited and transported from an upstream source. In addition, a small log jam of seven LWD pieces and numerous smaller sized woody debris were noted just downstream of the dam along the left bank. The source of this wood is unknown, but it could have been either floated over the dam during high flows, or been recruited from stream-side trees below the dam.

There is some potential for hill slope recruitment directly to the reservoir, but the small area and flatter terrain surrounding the diversion and dam limits the possibility of any large amounts of woody debris being stored behind the dam.

The amount of LWD observed upstream and downstream of the diversion was similar. Upstream of North Fork Long Canyon at least 20 pieces longer than 15 feet and at least one log jam consisting of six or more pieces of LWD were observed within the first mile. Downstream of the diversion, at least 35 pieces of wood longer than 15 feet were observed in 2006 along the first mile (PCWA 2007b).

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Table AQ 9-1. V* and Bulk Spawning Gravel Sampling Locations.

River/Reach	Bypass Reach	Peaking Reach	Total number of bulk spawning gravel samples collected	Recommended total number of pools for V* survey	Total number of V* pools surveyed in 2006	Total number of V* pools surveyed in 2007	Total number of V* pools not surveyed due to access conditions
Duncan Creek							
Duncan Creek	●		4	10	0	10	0
Middle Fork American River							
French Meadows – Interbay	●[1]		9	20	2	15	3
Interbay – Ralston	●		4	10	6	3	1
Below Ralston		●[1]	8	10	0	8	2
Rubicon River							
Hell Hole– South Fork Rubicon River	●		4	10	0	9	1
South Fork Rubicon River– Ralston	●[1]		8	20	1	17	2
Long Canyon Creek							
North Fork Long Canyon (NFLC)	●		4	10	0	10	0
South Fork Long Canyon Creek (SFLC)	●		4	10	0	10	0
Long Canyon Creek (LC)	●		5	10	0	9	1
Comparison Streams							
North Fork of the Middle Fork American River (NFMF)			4	10	3	0	7
North Fork American River (NF)			4	5	0	5	0
	Total:		**58**	**125**	**12**	**96**	**17**

[1]Two instream flow study sites are located along the reach.

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Table AQ 9-2. V*Measurement Results 2006 and 2007.

Stream	Pool Number	River Mile	Avg Length (ft)	Avg Width (ft)	Pool Bed Surface Area (ft^2)	Avg Residual Pool Volume (ft^3)	Avg Fines Thickness (ft)	Avg Fines Surface Area (ft^2)	Avg Volume Fine Sediment (ft^3)	Calculated V*
Duncan Creek										
Duncan Creek	1	6.16	72	7	504	1638	<0.1	trace	trace	<0.001
	2	6.53	45	30	1350	1350	0.0	0.0	0.0	0.000
	3	6.47	51	1	68	119	0.2	3.0	0.6	0.005
	4	6.41	45	30	1350	6075	0.0	0.0	0.0	0.000
	5	6.37	51	12	612	1224	0.1	3.0	0.3	0.0002
	6	6.35	54	6	324	486	<0.1	trace	trace	<0.001
	7	6.34	78	8	624	624	<0.1	trace	trace	<0.001
	8	6.3	39	45	1755	3510	<0.1	trace	trace	<0.001
	9	6.28	54	18	972	1944	0.2	16.0	3.2	0.002
	10	6.2	60	8	480	720	0.0	0.0	0.0	0.000
									Weighted 2007 V*	**0.0002**
Middle Fork American River (MFAR)										
French Meadows to Interbay	1	45	81	30	2430	7290	0.3	30	9	0.001
	2	44.92	51	30	1530	3060	<0.1	trace	trace	<0.001
	3	44.9	87	36	3132	3132	0.2	56	11	0.004
	4	44.9	87	24	2088	3132	0.3	11	3	0.001
	5	44.89	45	36	1620	6480	0.0	0	0	0.000
	6	44.89	69	45	3105	7763	0.2	10	2	0.0002
	7	44.86	114	36	4104	5130	0.8	455	364	0.071
	8	44.83	69	33	2277	3416	0.0	0	0	0.000
	9	44.8	69	33	2277	3416	0.3	114	34	0.010
	10	44.79	45	33	1485	4455	0.1	45	5	0.001
	11	36.25	177	65	11417	42241	<0.1	trace	trace	<0.001
	12	36.2	117	34	3978	11934	0.0	0	0	0.000
	13	36.18	102	33	3366	6732	<0.1	trace	trace	<0.001
	14	36.16	36	57	2052	8208	<0.1	trace	trace	<0.001
	15	36.11	219	45	9855	44348	<0.1	trace	trace	<0.001
									Weighted 2007 V*	**0.003**
	16	36.06	168	50	8400	11797	0.2	895	179	0.020
	17	35.98	221	55	12155	7263	0.3	1150	345	0.030
									Weighted 2006 V*	**0.027**
Interbay to Ralston	1	29.4	164	52	8528	23368	0.1	5220	522	0.020
	2	29.3	208	40	8320	2600	0.1	830	83	0.030
	3	29.25	175	33	5775	12343	0.4	102	41	0.003
	4	29.2	106	63	6678	1080	0.2	395	79	0.070
	5	26.08	173	58	10034	12269	0.2	2280	456	0.040
	6	25.94	268	46	12328	16722	0.2	2880	576	0.030
									Weighted 2006 V*	**0.025**
	7	26.69	165	45	7425	18563	<0.1	trace	trace	<0.001
	8	26.36	150	39	5850	23400	0.0	0	0	0.000
	9	26.29	147	42	6174	16670	0.0	0	0	0.000
									Weighted 2007 V*	**0.000**
Below Ralston	1	14.8	1155	96	110880	388080	0.1	2880	288	0.003
	2	14.35	270	75	20250	70875	0.3	220	66	0.003
	3	14.25	660	81	53460	294030	0.1	3116	312	0.006
	4	13.9	825	150	123750	618750	0.4	8800	3520	0.028
	5	13.6	819	75	61425	307125	0.1	180	18	0.0003
	6	4.6	420	120	50400	705600	0.5	7200	3600	0.071
	7	4.2	942	90	84780	763020	0.2	2100	420	0.005
	8	3.7	822	99	81378	732402	0.2	6105	1221	0.015
									Weighted 2007 V*	**0.002**
Rubicon River										
Hell Hole to South Fork Rubicon River	1	25.91	429	63	27027	101351	0.8	275	220	0.002
	2	25.81	228	45	10260	12825	0	0	0	0.000
	3	25.71	213	45	9585	16774	0.1	200	20	0.001
	4	25.63	246	63	15498	42620	0.5	2000	1000	0.023
	5	25.46	204	30	6120	7650	0	0	0	0.000
	6	25.37	138	60	8280	35190	0.1	300	30	0.001
	7	25.28	114	36	4104	7182	0.0	0	0	0.000
	8	25.06	357	45	16065	40163	0.1	10	1	0.00002
	9	25.01	138	27	3726	7825	<0.1	trace	trace	<0.001
									Weighted 2007 V*	**0.005**

Table AQ 9-2. V* Measurement Results 2006 and 2007 (continued).

Stream	Pool Number	River Mile	Avg Length (ft)	Avg Width (ft)	Pool Bed Surface Area (ft^2)	Avg Residual Pool Volume (ft^3)	Avg Fines Thickness (ft)	Avg Fines Surface Area (ft^2)	Avg Volume Fine Sediment (ft^3)	Calculated V*
Rubicon River (continued)										
South Fork Rubicon River to Ralston	1	21.17	243	54	13122	52488	1.5	150	225	0.004
	2	21.05	447	69	30843	138794	1.0	6000	6000	0.043
	3	20.9	60	45	2700	2700	0.0	0	0	0.000
	4	20.78	240	69	16560	53820	0.1	1125	113	0.002
	5	20.74	165	36	5940	17820	0.0	0	0	0.000
	6	20.64	216	57	12312	24624	<0.1	trace	trace	<0.001
	7	20.45	534	60	32040	16020	0.0	0	0	0.000
	8	20.25	315	63	19845	89303	0.0	0	0	0.000
	9	3.55	204	51	10404	20808	2.0	50	100	0.005
	10	3.48	534	78	41652	179104	<0.1	trace	trace	<0.001
	11	3.32	255	93	23715	213435	0.8	144	108	0.001
	12	3.18	360	66	23760	95040	<0.1	trace	trace	<0.001
	13	3	372	75	27900	97650	<0.1	trace	trace	<0.001
	14	1.6	330	66	21780	87120	0.8	400	320	0.005
	15	1.48	390	60	23400	198900	1.5	16200	24300	0.081
	16	1.14	300	71	21240	233640	0.1	2100	210	0.001
	17	0.91	285	75	21375	101531	<0.1	trace	trace	<0.001
									Weighted 2007 V*	**0.019**
	18	0.7	258	76	19608	58282	0.3	5460	1638	**0.030**
Long Canyon Creek										
North Fork Long Canyon Creek (NFLC)	1	2.03	30	12	360	270	0.3	30.0	9.0	0.025
	2	1.96	48	21	1008	2016	0.3	15.0	3.8	0.004
	3	1.94	55	7	385	385	0.2	5.0	0.8	0.002
	4	1.93	36	6	198	119	0.0	0.0	0.0	0.000
	5	1.9	10	13	130	65	0.1	1.0	0.1	0.001
	6	1.88	36	11	396	317	0.1	1.0	0.1	0.0003
	7	1.86	60	12	720	540	0.1	4.0	0.4	0.001
	8	1.84	19	8	152	76	0.2	4.5	0.9	0.006
	9	1.81	35	11	385	193	0.0	0.0	0.0	0.000
	10	1.79	39	6	234	94	<0.1	trace	trace	<0.001
									Weighted 2007 V*	**0.004**
South Fork Long Canyon Creek (SFLC)	1	2.59	19	13	247	198	<0.1	trace	trace	<0.001
	2	2.59	47	12	564	282	0.0	0.0	0.0	0.000
	3	2.57	87	21	1827	2375	0.2	85.3	12.8	0.007
	4	2.53	39	19	741	741	0.0	0.0	0.0	0.000
	5	2.45	113	16	1808	2712	0.1	50.0	5.0	0.003
	6	2.36	60	20	1200	1201	0.0	0.0	0.0	0.000
	7	2.34	90	18	1620	1620	<0.1	trace	trace	<0.001
	8	2.29	53	13	689	482	0.0	0.0	0.0	0.000
	9	2.26	95	18	1710	855	0.4	15.0	6.0	0.004
	10	2.23	100	18	1800	900	<0.1	trace	trace	<0.001
									Weighted 2007 V*	**0.002**
Long Canyon Creek (LCC)	1	9.09	63	17	1071	3481	0.0	0.0	0.0	0.000
	2	9.08	20	20	400	1200	0.0	0.0	0.0	0.000
	3	9.06	57	20	1140	2565	0.0	0.0	0.0	0.000
	4	9	96	42	4032	6048	0.0	0.0	0.0	0.000
	5	8.86	150	45	6750	5063	0.0	0.0	0.0	0.000
	6	8.8	96	75	7200	14400	0.0	0.0	0.0	0.000
	7	8.73	87	20	1740	3828	0.0	0.0	0.0	0.000
	8	8.61	42	51	2142	6426	<0.1	trace	trace	<0.001
	9	8.6	90	12	1080	2160	<0.1	trace	trace	<0.001
									Weighted 2007 V*	**0.000**
Comparison Stream										
North Fork American River (NFAR)	1	31.6	1017	120	122040	549180	0.0	0	0	0.000
	2	31.5	1200	90	108000	432000	5.0	1200	6000	0.014
	3	30.7	705	105	74025	740250	3.0	5000	15000	0.020
	4	30.4	840	90	75600	151200	0.0	0	0	0.000
	5	29.6	810	90	72900	200475	0.0	0	0	0.000
									Weighted 2007 V*	**0.010**
North Fork of the Middle Fork American River (NFMF)	1	2.9	146.2	53	7749	5086	0.2	1800	360	0.07
	2	2.85	176	47	8272	5332	0.1	1840	184	0.03
	3	2.75	75	35	2625	3455	0.2	610	122	0.03
									Weighted 2006 V*	**0.046**

Table AQ 9-3. Particle Size Results for Potential Spawning Gravel Samples.

Location	Instream Unit No.	Habitat Type[1]	River Mile	Spawning Gravel (SG)	Geometric Mean (mm)	D_{84} (mm)	D_{50} (mm)	D_{16} (mm)
Instream Flow Study Streams								
Duncan Creek								
D6.3	203	MCP	6.2	1	15.9	37.7	16.1	7.6
	193	MCP	6.3	2	11.6	26.1	11.6	5.2
	188	STP	6.36	3-R	16.2	40.7	18.4	6.1
	188	STP	6.36	4-R	17.6	50.0	22.3	6.0
Middle Fork American River								
MF44.7	728	STP	44.94	1	9.7	35.7	14.1	2.0
	721	MCP	44.86	2-R	9.6	32.9	15.2	1.8
	721	MCP	44.86	3-R	9.7	34.3	14.0	2.0
	717	MCP	44.8	4	7.4	29.0	10.0	1.4
MF36.1	694	RUN	36.17	1-R	9.0	33.5	9.7	3.6
	694	RUN	36.17	2-R	8.4	21.9	7.9	3.4
	694	RUN	36.17	3	11.1	65.5	9.6	2.8
	690	MCP	36.11	4	15.2	50.9	25.0	3.1
	690	MCP	36.11	5	12.3	39.6	16.0	3.3
MF26.2	334	HGR	26.32	1	11.5	38.5	18.1	2.1
	330	HGR	26.32	2	18.5	52.6	26.4	5.5
	327	POW	26.18	3-R	7.3	24.4	8.9	1.9
	327	POW	26.18	4-R	8.5	41.4	10.2	1.8
MF14.1	187	LGR	14.5	1-R	10.9	39.8	16.5	1.9
	187	LGR	14.5	2-R	17.5	54.0	26.1	4.5
	183	LSP	14.2	3	9.0	38.1	9.4	2.1
	177	SRN	13.64	4	21.2	63.7	39.0	5.0
MF4.8	83	SRN	4.72	1-R	9.9	46.6	16.1	1.3
	83	SRN	4.72	2-R	10.1	44.3	18.6	1.1
	81	MCP	4.61	3	16.4	46.1	22.9	6.8
	79	MCP	4.44	4	16.0	49.7	27.8	4.2
Rubicon River								
R25.7	820	MCP	25.91	1-R	17.0	39.9	18.7	8.9
	820	MCP	25.92	2-R	16.4	41.2	18.5	8.3
	807	LSP	25.63	3	16.5	55.5	24.2	3.7
	795	LGR	25.2	4	10.0	39.1	15.1	1.9
R20.9	679	MCP	20.87	1	11.7	34.6	15.6	3.3
	665	RUN	20.51	2	9.2	37.6	11.7	1.9
	662	MCP	20.4	3-R	6.1	20.7	7.5	1.5
	662	MCP	20.4	4-R	8.1	26.1	9.5	2.2
R3.5	81	MCP	3.31	1-R	19.5	67.9	28.2	5.0
	81	MCP	3.31	2-R	16.0	42.7	19.4	6.6
	76	MCP	3.12	3	12.8	52.9	15.1	3.2
	71	LSP	3.02	4	9.3	28.5	10.0	3.3

Table AQ 9-3. Particle Size Results for Potential Spawning Gravel Samples (continued).

Location	Instream Unit No.	Habitat Type[1]	River Mile	Spawning Gravel (SG)	Geometric Mean (mm)	D_{84} (mm)	D_{50} (mm)	D_{16} (mm)
Instream Flow Study Streams								
Long Canyon Creek								
North Fork Long Canyon Creek (NFLC1.9)	109	STP	1.94	1	12.9	99.4	11.8	2.6
	103	LSP	1.98	2	10.0	39.2	12.5	2.3
	93	SRN	2.06	3	11.4	51.1	15.0	2.1
	93	SRN	2.06	4	17.6	53.5	27.3	4.1
Long Canyon Creek (continued)								
South Fork Long Canyon Creek (SFLC2.3)	97	MCP	2.34	1[2]	11.5	54.5	17.1	2.0
	93	LSP	2.39	2	16.3	64.9	27.5	9.0
	77	SRN	2.53	3	16.8	62.1	22.7	3.9
	77	SRN	2.53	4	13.8	42.6	17.7	3.7
Long Canyon Creek (LC9.0)	136	RUN	8.84	1	32.2	105.5	38.8	9.2
	134	MCP	8.88	2	17.4	61.6	33.2	2.3
	131	LGR	8.98	3	25.6	107.8	28.8	2.3
	131	LGR	8.98	4	14.4	57.3	18.3	2.7
	126	STP	9.08	5	13.9	36.0	18.5	4.6
Comparison Streams								
North Fork American River (NF31.3)	*	MCP	31.25	1	9.9	18.2	10.6	5.8
	*	LGR	30.7	2	10.8	30.3	12.7	3.7
	*	LGR	30.7	3	11.1	25.0	12.2	5.2
	*	LGR	30.5	4	14.6	61.8	13.6	4.6
North Fork of the Middle Fork American River (NFMF2.3)	*	MCP	2.87	1	15.1	40.7	19.9	5.5
	*	POW	2.78	2	8.6	31.1	12.7	1.6
	*	MCP	2.74	3	7.8	28.0	11.3	1.3
	*	MCP	2.74	4	25.5	100.1	41.7	3.9

[1]MCP:mid channel pool; STP:step pool; LSP:lateral scour pool; SRN:step run; RUN:run; LGR:low gradient riffle; HGR:high gradient riffle; POW:pocket water

[2]Does not contain material from surface sample

"*": Instream unit number not applicable

R: Replicate side-by-side sample

Table AQ 9-4. Fine Sediment Content of Potential Spawning Gravel Samples.

Location	Instream Unit No.	Habitat Type[1]	River Mile	Spawning Gravel (SG)	Gravel Prior to Cleaning: Cumulative Percent Finer than 1 mm	Gravel Prior to Cleaning: Cumulative Percent Finer than 6.4 mm	Gravel Following Winnowing of Fine Sediment: Cumulative Percent Finer than 1 mm	Gravel Following Winnowing of Fine Sediment: Cumulative Percent Finer than 6.4 mm
Instream Flow Study Streams								
Duncan Creek								
D6.3	203	MCP	6.2	1	0.5%	10.0%	0.3%	6%
	193	MCP	6.3	2	0.2%	22.0%	0.2%	13%
	188	STP	6.36	3	0.4%	16.0%	0.3%	9%
	188	STP	6.36	4	1.0%	17.0%	0.7%	10%
Middle Fork American River								
MF44.7	728	STP	44.94	1	7.0%	**32.0%**	4.7%	19%
	721	MCP	44.86	2	8.1%	29.0%	5.4%	17%
	721	MCP	44.86	3	10.6%	**38.0%**	7.1%	22%
	717	MCP	44.8	4	7.5%	**32.0%**	5.0%	19%
MF36.1	694	RUN	36.17	1	2.1%	**31.0%**	1.4%	18%
	694	RUN	36.17	2	1.1%	**36.0%**	0.7%	21%
	694	RUN	36.17	3	4.1%	**39.0%**	2.7%	23%
	690	MCP	36.11	4	3.5%	19.0%	2.3%	11%
	690	MCP	36.11	5	3.3%	26.0%	2.2%	15%
MF26.2	334	HGR	26.32	1	8.1%	26.0%	5.4%	15%
	330	HGR	26.32	2	2.8%	17.0%	1.9%	10%
	327	POW	26.18	3	7.6%	**37.0%**	5.1%	21%
	327	POW	26.18	4	7.9%	**37.0%**	5.3%	21%
MF14.1	187	LGR	14.5	1	4.8%	**32.0%**	3.2%	19%
	187	LGR	14.5	2	3.9%	19.0%	2.6%	11%
	183	LSP	14.2	3	5.5%	**37.0%**	3.7%	21%
	177	SRN	13.64	4	5.8%	18.0%	3.9%	10%
MF4.8	83	SRN	4.72	1	12.1%	**33.0%**	8.1%	19%
	83	SRN	4.72	2	**14.7%**	**31.0%**	9.8%	18%
	81	MCP	4.61	3	9.1%	15.0%	6.1%	9%
	79	MCP	4.44	4	5.0%	20.0%	3.4%	12%
Rubicon River								
R25.7	820	MCP	25.91	1	2.7%	8.0%	1.8%	5%
	820	MCP	25.92	2	3.9%	10.0%	2.6%	6%
	807	LSP	25.63	3	2.7%	22.0%	1.8%	13%
	795	LGR	25.2	4	6.9%	**34.0%**	4.6%	20%
R20.9	679	MCP	20.87	1	3.3%	25.0%	2.2%	15%
	665	RUN	20.51	2	6.9%	**34.0%**	4.6%	20%
	662	MCP	20.4	3	10.6%	**42.0%**	7.1%	24%
	662	MCP	20.4	4	6.7%	**35.0%**	4.5%	20%
R3.5	81	MCP	3.31	1	4.0%	18.0%	2.7%	10%
	81	MCP	3.31	2	3.9%	15.0%	2.6%	9%
	76	MCP	3.12	3	5.6%	27.0%	3.8%	16%
	71	LSP	3.02	4	3.5%	30.0%	2.3%	17%

Table AQ 9-4. Fine Sediment Content of Potential Spawning Gravel Samples (continued).

Location	Instream Unit No.	Habitat Type[1]	River Mile	Spawning Gravel (SG)	Gravel Prior to Cleaning: Cumulative Percent Finer than 1 mm	Gravel Prior to Cleaning: Cumulative Percent Finer than 6.4 mm	Gravel Following Winnowing of Fine Sediment: Cumulative Percent Finer than 1 mm	Gravel Following Winnowing of Fine Sediment: Cumulative Percent Finer than 6.4 mm
Instream Flow Study Streams								
Long Canyon Creek								
North Fork Long Canyon Creek (NFLC1.9)	109	STP	1.94	1	4.6%	**31.0%**	3.1%	18%
	103	LSP	1.98	2	6.4%	**33.0%**	4.3%	19%
	93	SRN	2.06	3	4.9%	22.0%	3.3%	13%
	93	SRN	2.06	4	4.2%	20.0%	2.8%	12%
South Fork Long Canyon Creek (SFLC2.3)	97	MCP	2.34	1	7.4%[2]	**32%[2]**	5%[2]	19%[2]
	93	LSP	2.39	2	9.5%	22.0%	6.4%	13%
	77	SRN	2.53	3	4.7%	20.0%	3.1%	12%
	77	SRN	2.53	4	2.1%	24.0%	1.4%	14%
Long Canyon Creek (LC9.0)	136	RUN	8.84	1	0.9%	10.0%	0.6%	6%
	134	MCP	8.88	2	9.3%	21.0%	6.2%	12%
	131	LGR	8.98	3	1.6%	16.0%	1.1%	9%
	131	LGR	8.98	4	4.2%	29.0%	2.8%	17%
	126	STP	9.08	5	2.4%	20.0%	1.6%	12%
Comparison Streams								
North Fork American River (NF31.3)	*	MCP	31.25	1	3.1%	17.0%	2.1%	10%
	*	LGR	30.7	2	12.4%	**32.0%**	8.3%	19%
	*	LGR	30.7	3	**14.1%**	**33.0%**	9.4%	19%
	*	LGR	30.5	4	3.5%	19.0%	2.3%	11%
North Fork of the Middle Fork American River (NFMF2.3)	*	MCP	2.87	1	1.2%	16.0%	0.8%	9%
	*	POW	2.78	2	3.0%	25.0%	2.0%	15%
	*	MCP	2.74	3	1.1%	19.0%	0.7%	11%
	*	MCP	2.74	4	1.2%	22.0%	0.8%	13%

[1]MCP:mid channel pool; STP:step pool; LSP:lateral scour pool; SRN:step run; RUN:run; LGR:low gradient riffle; HGR:high gradient riffle; POW:pocket water
[2]Does not contain fine sediment content from surface sample
"*" Instream unit number not applicable
Bold indicates fine sediment threshold exceeded

Table AQ 9-4. Fine Sediment Content of Potential Spawning Gravel Samples (continued).

Location	Instream Unit No.	Habitat Type[1]	River Mile	Spawning Gravel (SG)	Gravel Prior to Cleaning: Cumulative Percent Finer than 1 mm	Gravel Prior to Cleaning: Cumulative Percent Finer than 6.4 mm	Gravel Following Winnowing of Fine Sediment: Cumulative Percent Finer than 1 mm	Gravel Following Winnowing of Fine Sediment: Cumulative Percent Finer than 6.4 mm
Instream Flow Study Streams								
Long Canyon Creek								
North Fork Long Canyon Creek (NFLC1.9)	109	STP	1.94	1	4.6%	**31.0%**	3.1%	18%
	103	LSP	1.98	2	6.4%	**33.0%**	4.3%	19%
	93	SRN	2.06	3	4.9%	22.0%	3.3%	13%
	93	SRN	2.06	4	4.2%	20.0%	2.8%	12%
South Fork Long Canyon Creek (SFLC2.3)	97	MCP	2.34	1	7.4%[2]	**32%[2]**	5%[2]	19%[2]
	93	LSP	2.39	2	9.5%	22.0%	6.4%	13%
	77	SRN	2.53	3	4.7%	20.0%	3.1%	12%
	77	SRN	2.53	4	2.1%	24.0%	1.4%	14%
Long Canyon Creek (LC9.0)	136	RUN	8.84	1	0.9%	10.0%	0.6%	6%
	134	MCP	8.88	2	9.3%	21.0%	6.2%	12%
	131	LGR	8.98	3	1.6%	16.0%	1.1%	9%
	131	LGR	8.98	4	4.2%	29.0%	2.8%	17%
	126	STP	9.08	5	2.4%	20.0%	1.6%	12%
Comparison Streams								
North Fork American River (NF31.3)	*	MCP	31.25	1	3.1%	17.0%	2.1%	10%
	*	LGR	30.7	2	12.4%	**32.0%**	8.3%	19%
	*	LGR	30.7	3	**14.1%**	**33.0%**	9.4%	19%
	*	LGR	30.5	4	3.5%	19.0%	2.3%	11%
North Fork of the Middle Fork American River (NFMF2.3)	*	MCP	2.87	1	1.2%	16.0%	0.8%	9%
	*	POW	2.78	2	3.0%	25.0%	2.0%	15%
	*	MCP	2.74	3	1.1%	19.0%	0.7%	11%
	*	MCP	2.74	4	1.2%	22.0%	0.8%	13%

[1]MCP:mid channel pool; STP:step pool; LSP:lateral scour pool; SRN:step run; RUN:run; LGR:low gradient riffle; HGR:high gradient riffle; POW:pocket water

[2]Does not contain fine sediment content from surface sample

"*" Instream unit number not applicable

Bold indicates fine sediment threshold exceeded